CONEXANT™

Advanced Packaging of Image Sensors

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Image Sensors: the heart of digital cameras

Images taken with Conexant
SXGA (1280 × 1024)
1.3 megapixel image sensor

Outline

- Special requirements for image sensor packaging
- Traditional packaging for digital still cameras
- Additional requirements for wireless handset camera modules
- Case #1: Encapsulated package
- Case #2: Chip scale package

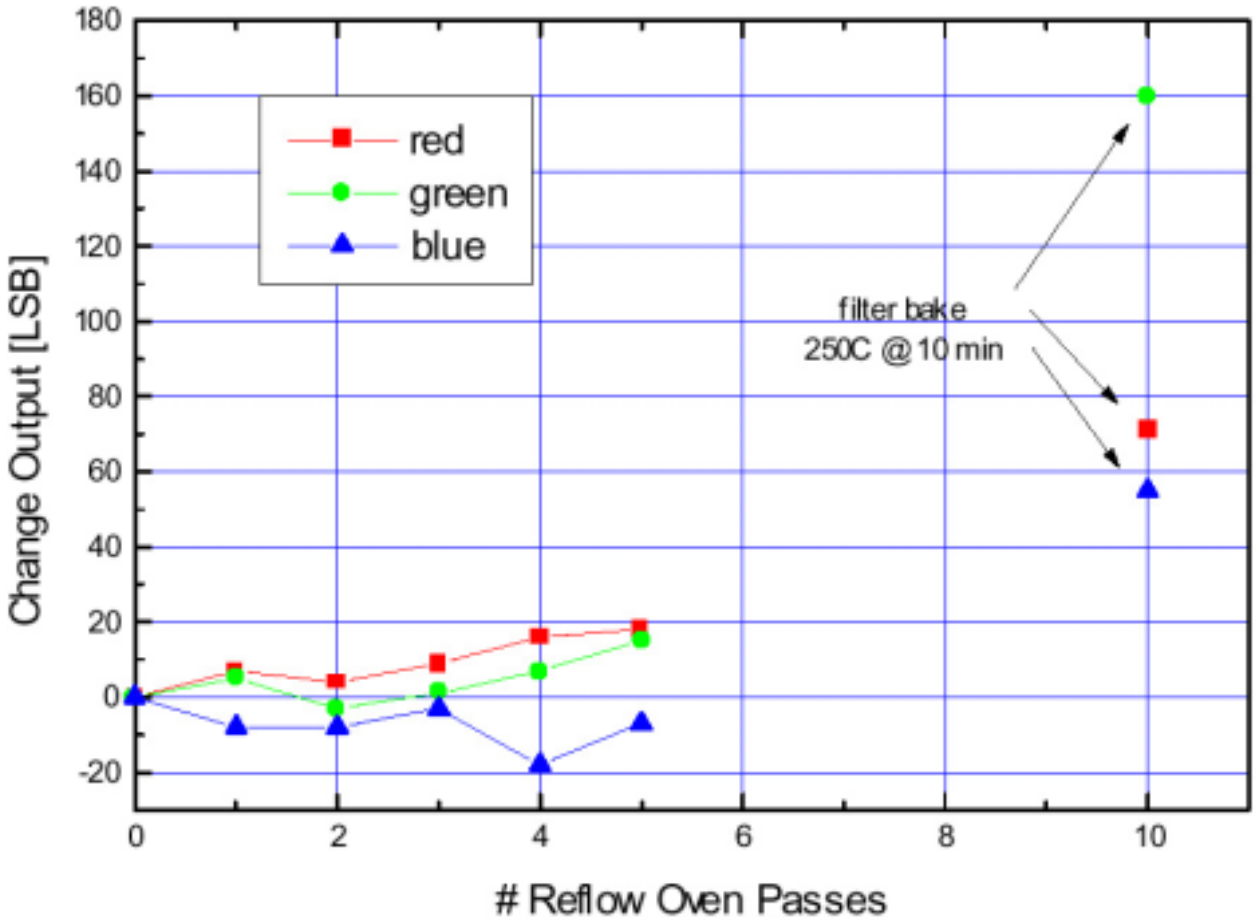
Special packaging requirements

- Limited process temperatures
- Optically transparent material
- Contamination control during packaging
- Alignment of image sensor package to optics mechanism
- Package Test

Limited process temperatures

- **Two types of color filter materials:**
- **Organic dyes**
  - Maximum process temperatures can be limited to 150°C or lower
  - May require low temperature die attach process and low temperature wirebonding
  - Might not be solder reflow compatible
- **Pigments**
  - Allows higher process temperatures
  - Can be solder reflow compatible
- **Microlens materials can also be affected by temperature**

Effect of temperature on color filters



After 250ºC bake
Red: -9%
Green: -24%
Blue: -8%

Red - Cyan
Green - Magenta
Blue - Yellow

Optically transparent materials

- **Choices are limited:**
- **Glass**
  - 98-99% transmittance of visible light
  - expensive
  - difficult to handle
- **Clear Organics**
  - 90-92% transmittance of visible light
  - susceptible to degradation
  - large thermal expansion mismatch with die

Optically transparent materials, cont.

Glass lid

Organic - after 3 passes of solder reflow

Contamination control

- VGA-format image sensors contain over 300,000 pixels
- Typical pixel sizes range from 5-10 µm and are shrinking
- Contamination on die surface can be visible in image
- May be possible to correct for bad pixels in software
- Contamination far from the die surface is not in focus

Alignment of sensor to optics

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- Wide range of techniques for image sensor-optics alignment:
- Low end “toy” digital cameras: simple assembly with no real alignment
- High-end digital cameras: precision active alignment, e.g. 6-axis robotic alignment fixtures
- Middle ground: passive alignment of image sensor and optics to the same datum features

Package test

- Cannot contact surface of package above the active area of the image sensor, but must make reliable contact
- Must integrate a well-characterized and well-calibrated light source into the test handler (e.g. Tungsten-Halogen 3200°K)
- Must maintain flatness and parallelism if testing with optics

Traditional Imager Packaging Approach

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- Ceramic or Plastic cavity package (LCC) with glass lid
- Package cost is high based on number of I/O
- LCC form factor is too large and expensive for embedding into wireless handsets

Wireless handset camera module

- **Customer requirements:**

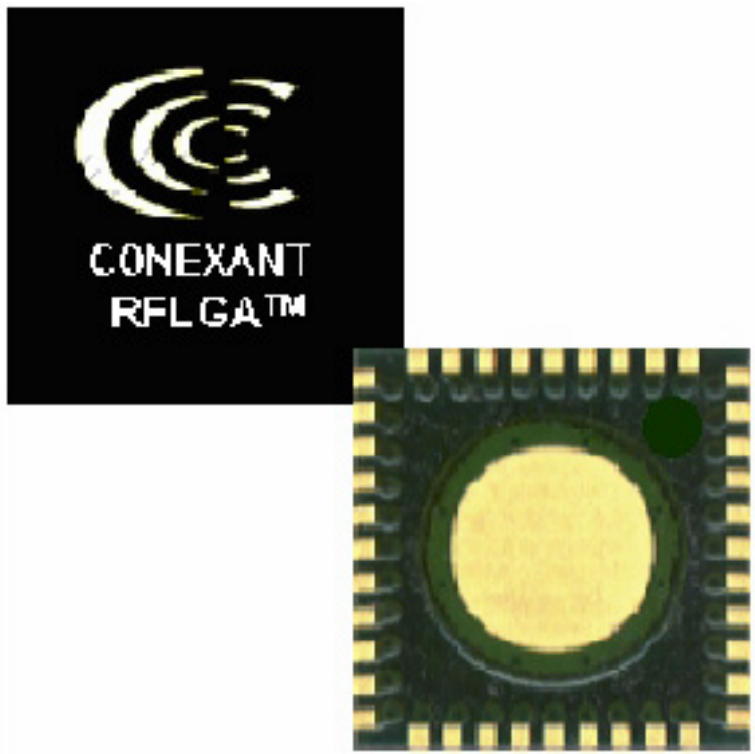
- **CIF or VGA format image sensor; both still and video imaging**
- **Integrated optics assembly and image-processing ASIC**
- **2.7V power supply; power consumption < 100 milliwatts**
- **Complete module occupies < 1 cc**
- **Total price for sensor, package, optics, and ASIC < $10**

- **Low Z-height is one of the most critical parameters for wireless handsets manufacturers**

EETimes 9/8/00

Case #1: Encapsulated Imager Package

- **Modeled on Conexant's Radio Frequency Land Grid Array Overmolded Package (used for transceivers)**

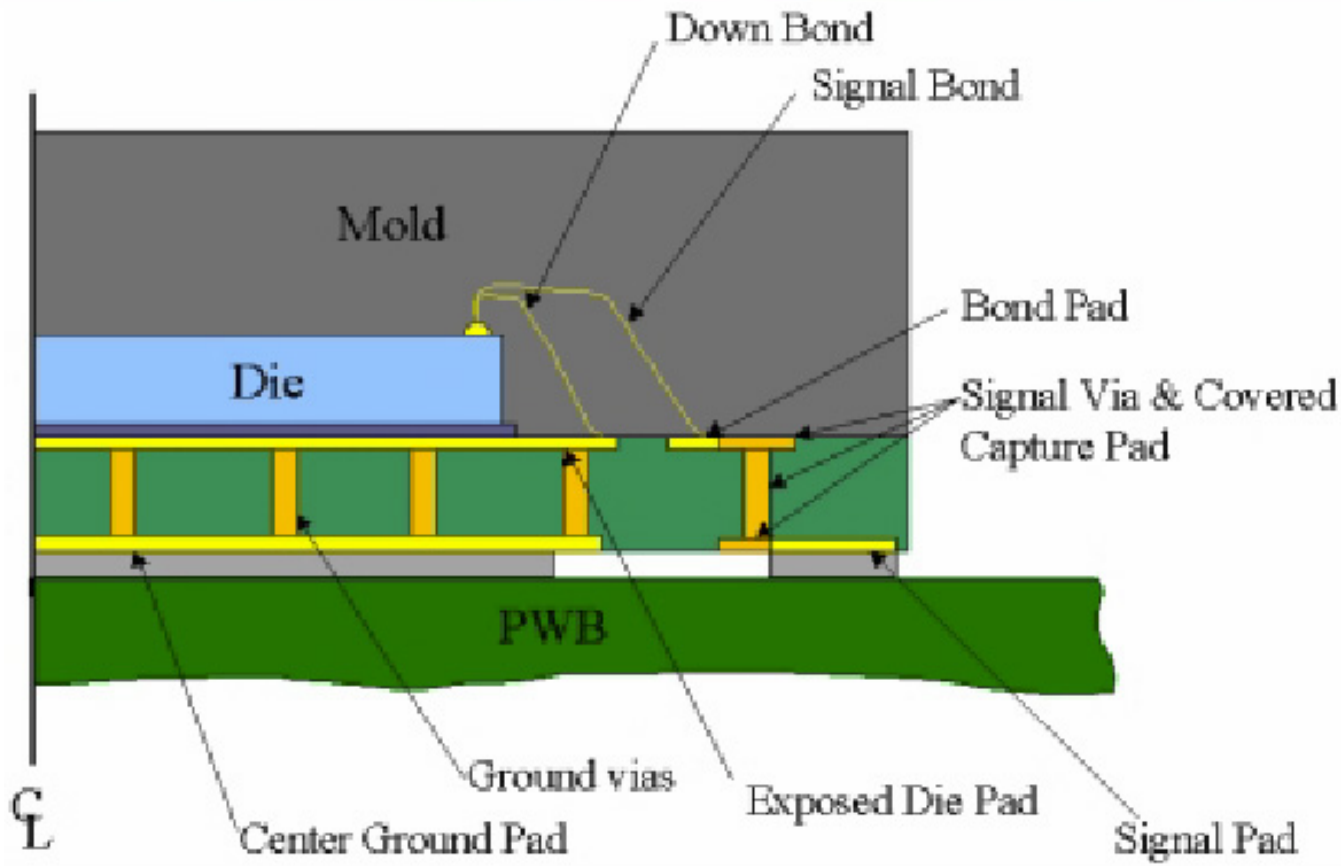


Top and bottom view of a 6x6, 40 pin RFLGA.

Advantages:

- In-house assembly and test capability
- Low cost, high volume product
- Thin form factor

Optical Land Grid Array Package



Half-symmetric representation of a typical RFLGA cross section.

- **Replace overmold with dam-and-fill (clear encapsulant)**

Optical LGA Process Flow

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- **Wafer Saw**
- **Die Attach to laminate substrate**
- **Plasma Clean**
- **Wire Bond**
- **Dam and Fill - *Dispensing or Printing****
- **Branding***
- **Saw Singulation of matrix***
- **Electrical and optical testing***

** new process development required*

Transmission through encapsulant

- Clear encapsulant material transmits 90-92% of visible light
- Solder reflow had minimal impact on image quality

Glass lid

Encapsulated - after 3 passes of solder reflow

Optical Characterization

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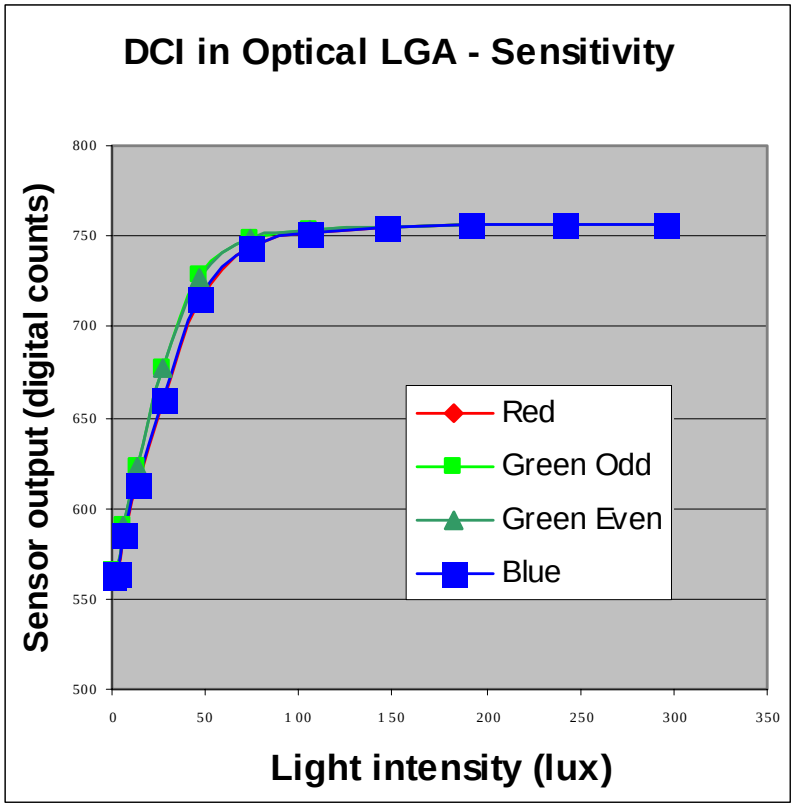
Optical LGA				CLCC			
Sensitivity	(counts/lux.sec)			Sensitivity	(counts/lux.sec)		
	Channel				Channel		
Red	Green	Blue		Red	Green	Blue	
22.15	26.04	22.57		28.77	34.81	31.71	
	PRNU @ 1.2lux(%)				PRNU @ 1.2lux(%)		
	Channel				Channel		
Red	Green	Blue		Red	Green	Blue	
2.47	1.92	3.3		1.65	1.39	1.52	
Noise				Noise			
PTN	0.238845	counts		PTN	0.1656567	counts	
PFPN	0.998999	counts		PFPN	1.3694735	counts	
CFPN	52.99283	counts		CFPN	52.892271	counts	
RFPN	0.154281	counts		RFPN	0.1109943	counts	
RTN	0.016778	counts		RTN	0.0190503	counts	
CTN	0.014118	counts		CTN	0.0100404	counts	

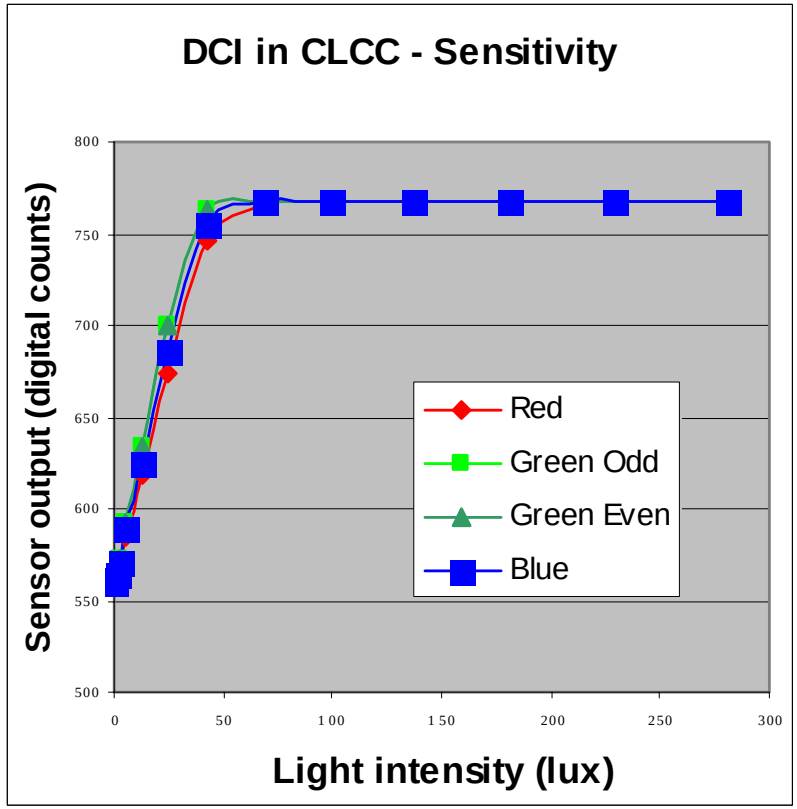
Photosensitivity in red, green, & blue channels

Pixel Response Non-Uniformity in flat field (no lens)

Noise (measured “in the dark”)

Optical Characterization, cont.





The Optical LGA and CLCC had similar sensitivity, pixel response non-uniformity, and noise values.

Optical LGA Reliability

- JEDEC Level 4 Preconditioning
- 85°C / 85% RH
- Thermal Cycling
- 125°C High Temperature Storage
- 10,000 Lux Light Exposure

- Failures seen after 85/85 and thermal cycling

- C-SAM shows delamination of encapsulant from substrate due to CTE mismatch

Optical LGA Feasibility Summary

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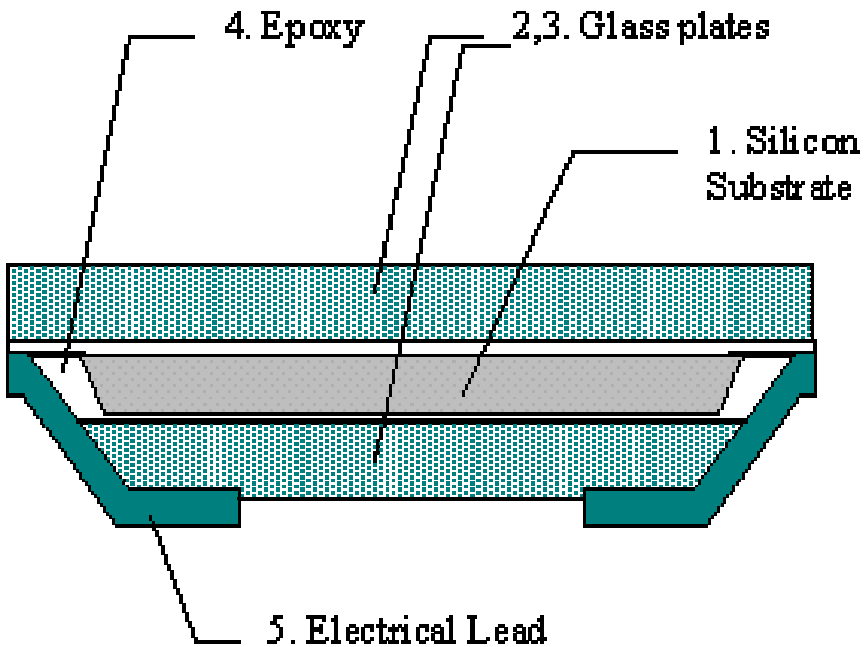
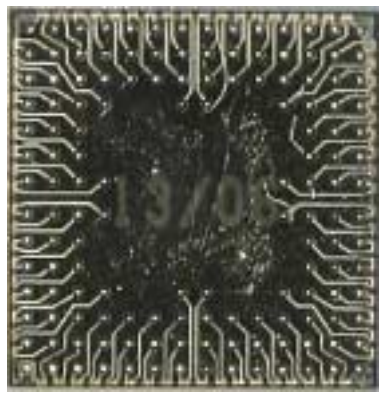
- **Optical Performance & Characterization**
  - **Preliminary results show comparable performance between Optical LGA package and CLCC**
- **Package Reliability**
  - **Package delamination failures seen - due to CTE mismatch between clear encapsulant and substrate**
- **Future Work**
  - Investigate alternate clear encapsulant materials with lower CTE

Case #2: Chip Scale Imager Package

- **Wafer-level CSP**
- **Smaller, thinner, and lower cost than Optical LGA**

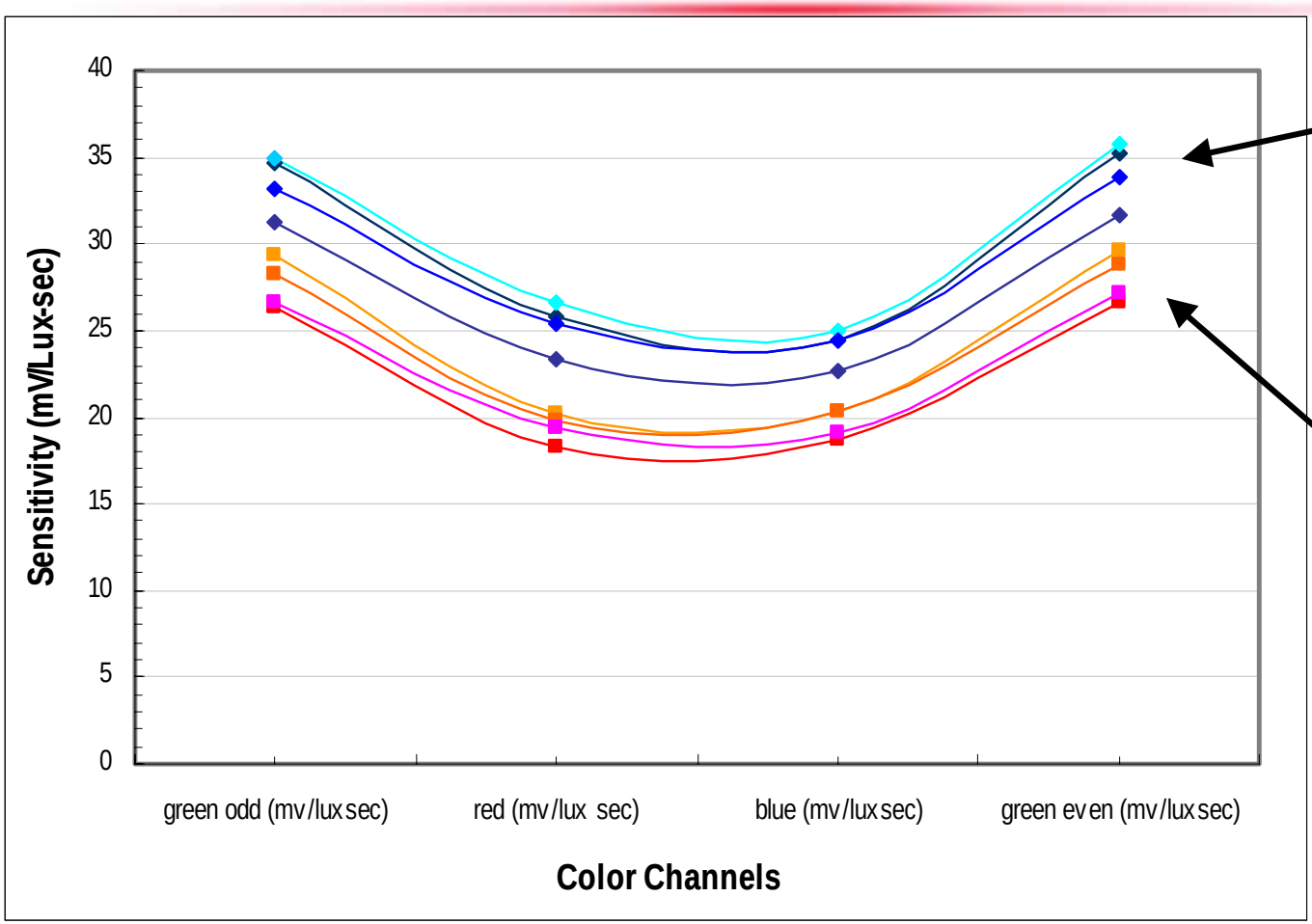




Optical Characterization

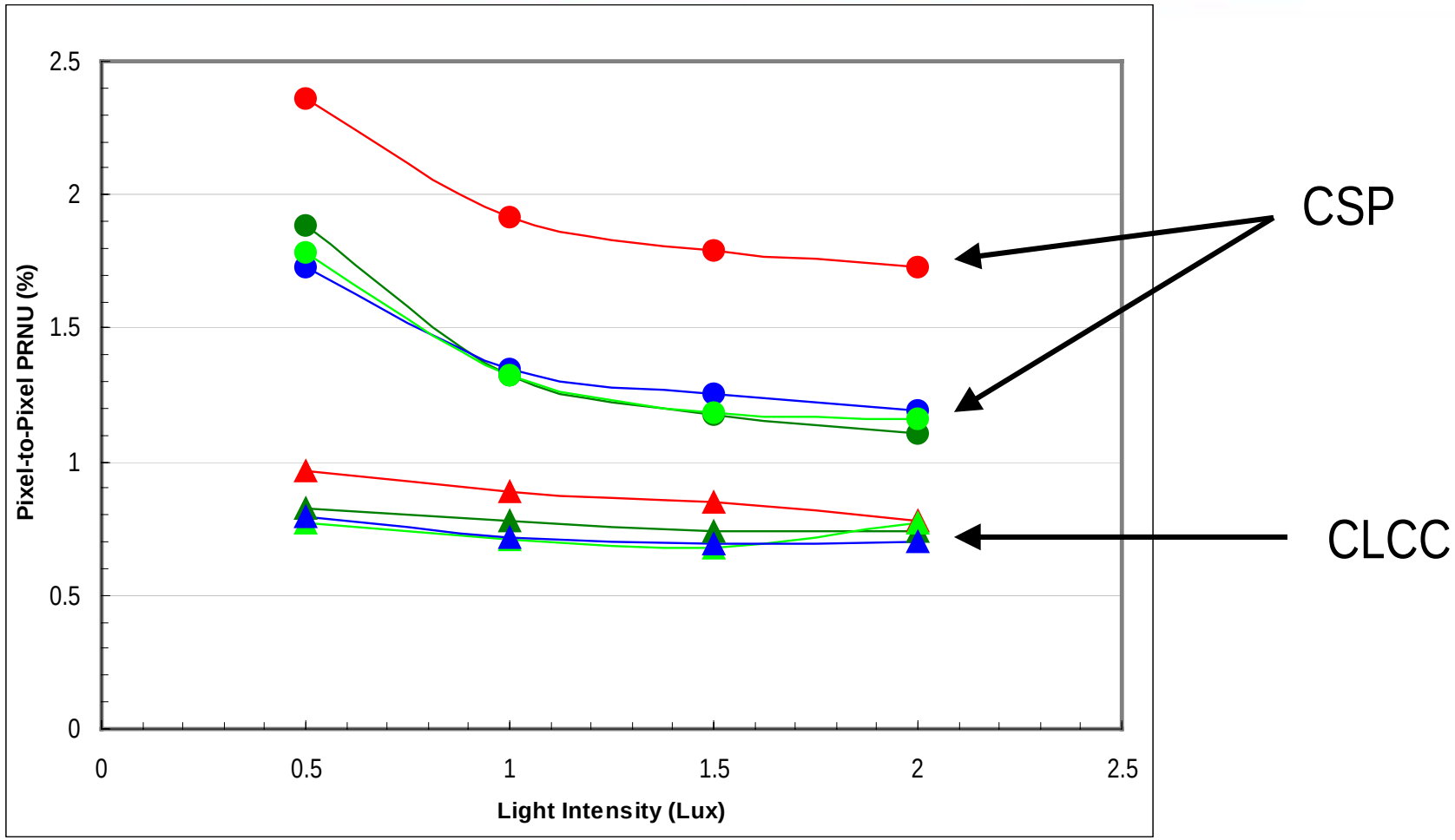
- **Compared CSP to CLCC performance with Conexant SXGA die**
  - Photosensitivity in R, G, and B
  - Pixel Response Non-Uniformity
  - Noise
  - Power Consumption
- **Expect that construction of CSP will reduce benefit of microlenses (no air gap - smaller Δ in refractive index)**
- **Maximum benefit of microlens in this system is 2X**

Photosensitivity



- CSP has 15-20% less sensitivity than CLCC
- Red and Blue responses lower than Green for both packages

Pixel Response Non-Uniformity



- CSP has higher PRNU, but within acceptable range
- Higher Red PRNU due to higher cross-talk

Noise and Power Consumption

- No distinct difference between CLCC and CSP in column fixed pattern noise and pixel fixed pattern noise
- No difference in power consumption

CSP Reliability

- Because of limited sample size, concentrated on temperature cycling and 85/85

- JEDEC Level 4 Preconditioning
- 85°C / 85% RH
- Thermal Cycling

- No failures seen

CSP Imager Package Summary

- Performance is similar to CLCC package, except for some degradation in photosensitivity
- Preliminary reliability results encouraging, need more thorough evaluation

- Challenges: automated test of small, thin imager sensor package